VCAT Status Report
Center for Nanoscale Science and Technology

Robert Celotta, Director

VCAT Meeting

September 12, 2006 – NIST Boulder Laboratories

(http://cnst.nist.gov)

Outline

- CNST's Mission
- The Last 90 Days
- Overarching Themes
- Existing Programs
- New Program Directions

CNST Mission

- CNST will
  - provide measurement methods, standards and technology to support all phases of nanotechnology development from discovery to production,
  - develop and maintain a national facility, the Nanofab, with state-of-the-art, nanoscale fabrication and measurement capabilities
  - apply a multidisciplinary approach to problem solving that involves partnering with industry, academia, and other government agencies,
  - serve as a hub to link the external nanotechnology community to the vast measurement expertise that exists within the NIST Laboratories, and
  - help to educate the next generation of nanotechnologist.

CNST Structure

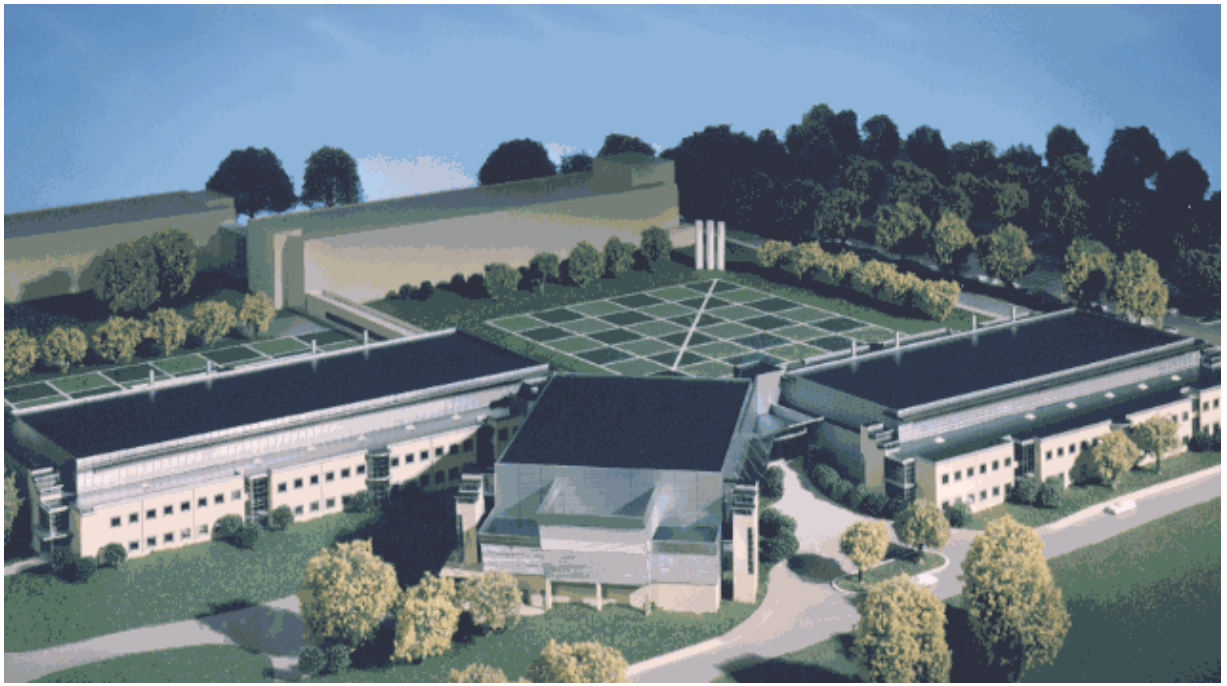
- The CNST consists of a Research Program and the CNST Nanofab
  - The Research Program
    - Enabling nanotechnology with measurement solutions
  - The Nanofab
    - A National User Facility with state-of-the-art measurement and fabrication capabilities

Since we met last…

- University Partnership Established
  - University of Maryland will partner with CNST
  - University Staff and Faculty will participate in measurement research in CNST and the Nanofab
  - 7.5M$ over 5 years
  - Ellen Williams, Principle Investigator
  - Coordinated with the University of Maryland Nanocenter

Since we met last…

- Plans are in now in motion to provide the needed space for CNST laboratories, staff, and Nanofab users in the AML facility.
- CNST will leverage the facilities of the AML – arguably the world's most advanced laboratory – for its nanotechnology research.



Since we met last…

The Nanofab has…

- Brought on-line
  - A nano-imprint lithography tool (Nanonex NX-2000)
  - A deep silicon etcher (Bosch process)
  - A microwave plasma asher
  - A critical point dryer
  - A vacuum sealer, wire bonder, dicing saw
  - Front and back alignment capability on the MA-6 aligner
  - A new lift-off photoresist process allowing definition of metal patterns as thin as 20nm with 250 nm linewidth
- Enhanced operations and communications
  - A new website was introduced
  - A user forum was created allowing efficient communication between Nanofab users for matters relating to process, equipment, policy, etc.
  - A new multi-terminal computer system (Coral/Sunray) to streamline tool control and user validation

Nanofab User Policy (Draft)

- The CNST Nanofab will be operated as a fee based, shared use, nanofabrication and nanoscale measurement facility
- It will be open to all users, both internal and external, upon the approval of a brief proposal
- Fees for the use of various tools are based on their full operating costs, including supplies, maintenance contracts, labor, training, etc. Fees similar to the full cost recovery fees of the NSF nanocenters are intended.
- Internal users, whose projects are in support of either the CNST or NIST missions, would have a portion of their fee paid by CNST as its contribution to the support of the research.
- After the CNST contribution, the net charges paid by internal users are intended to approximate the “academic rates” charged by the major NSF Nanocenters.

Nanofab User Policy (Draft)

- External users, e.g., industry, academia, or government, would generally pay the full fee, but could apply to have a portion of their fee waived as a CNST contribution to their research.
- The Nanofab will train users in use of the fabrication and measurement tools.
- Alternatively, users can have the entire fabrication and/or measurement process performed by one of the Nanofab process engineers by paying additional costs.
- Users typically begin this process by discussing what they wish to accomplish with Dr. Gerard Henein, the Nanofab Manager
- Alternatively, if the fabrication or measurement problem transcends the standard methods, a joint research project with a member of the CNST research program might be appropriate. For nanofabrication problems, Dr. Alex Liddle would be appropriate contact.

CNST's Research Program Areas of Concentration

- Program areas reflect the measurement needs of emerging nanotechnologies
- Identification process is thorough and continuous
  - US Measurement System Survey
  - Government Reports (NNI, European, Asian, etc.)
  - Direct Industrial Contacts (GE, Motorola, Intel, SIA, TIA, Zyvex, Agilent, etc.)
  - Research Community Input (Meetings, workshops, reports, advisory board, etc.)
  - NIST Laboratory Staff (NanoSWG, and direct contact)
  - CNST Research Staff (Leading experts in their fields)

Areas of Concentration

Measurements for:

- Post - CMOS Electronics
  - Devices, architectures, interconnects
- Nanomanufacturing and Nanofabrication
  - Top-down and bottom-up fabrication and assembly
- Energy
  - Conversion, storage, and transport

Initial Research Projects

- Advanced focused ion beams for nanofabrication and precise doping
- Atom-based metrology
- Modeling and simulation
- Nanomagnetic device imaging
- Atomic scale characterization and fabrication
  - Atomic scale electronics
  - Graphene electronics

Atomic Scale Electronics

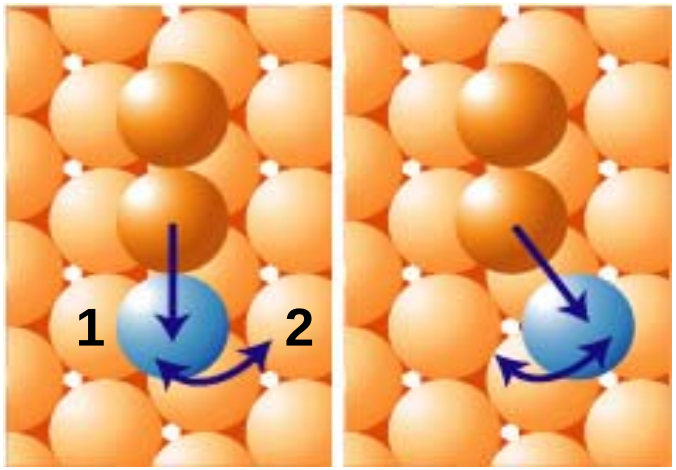
- What if you could replace a macroscopic electrical switch by one on the atomic scale?

Mechanical Switch

Atomic Switch

Towards A Single Atom Switch

- For a “wire” of atoms resting atop an ordered atomic lattice, this might correspond to making a single atom move to an adjacent crystal lattice site.



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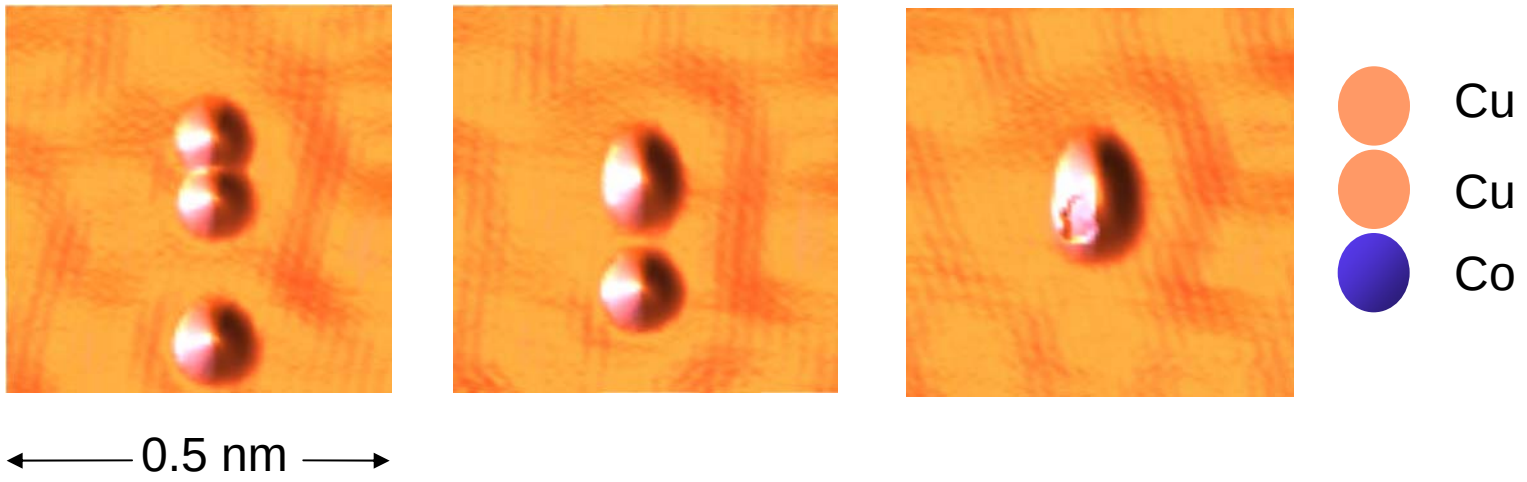
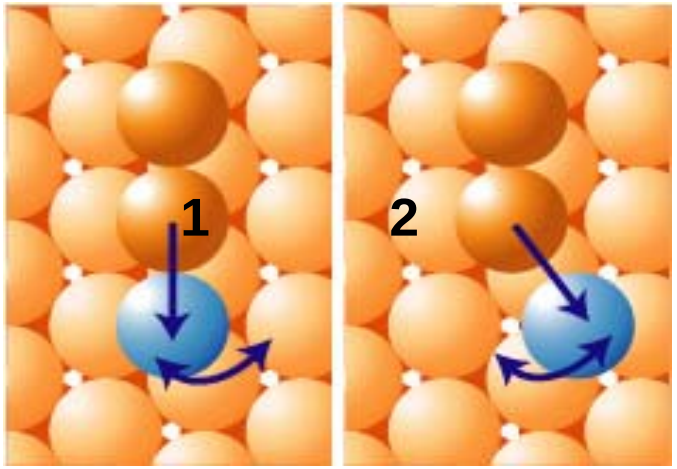
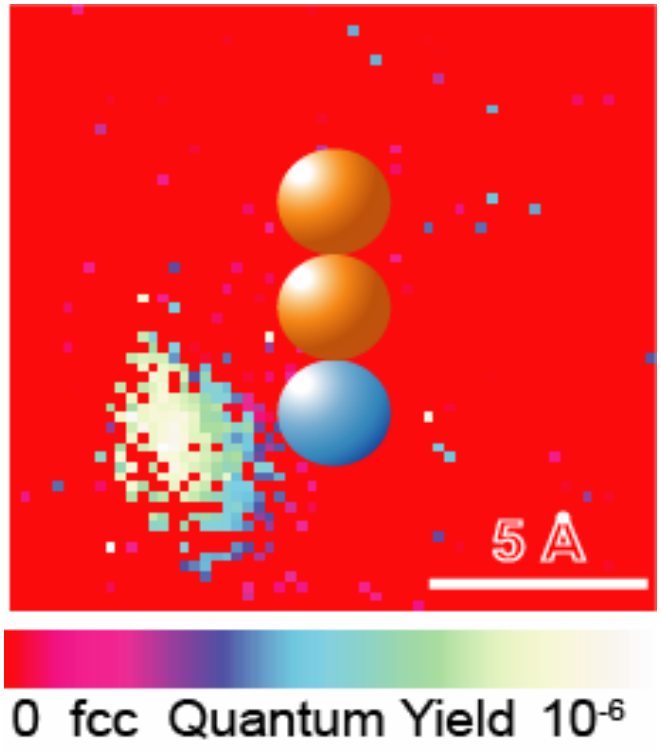


Towards A Single Atom Switch

- Where, exactly, would you inject charge to make the atom switch?





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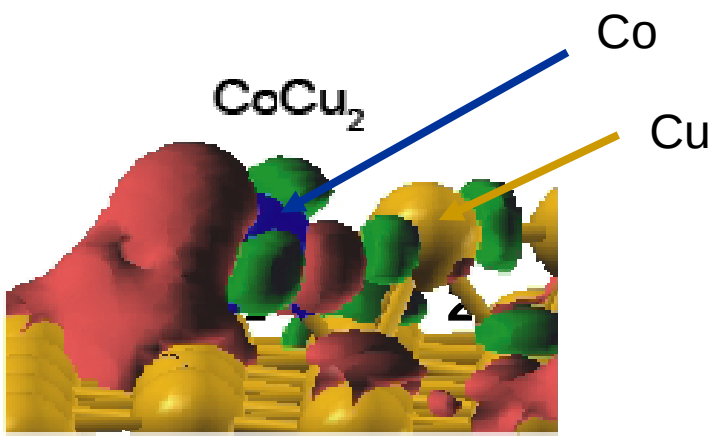
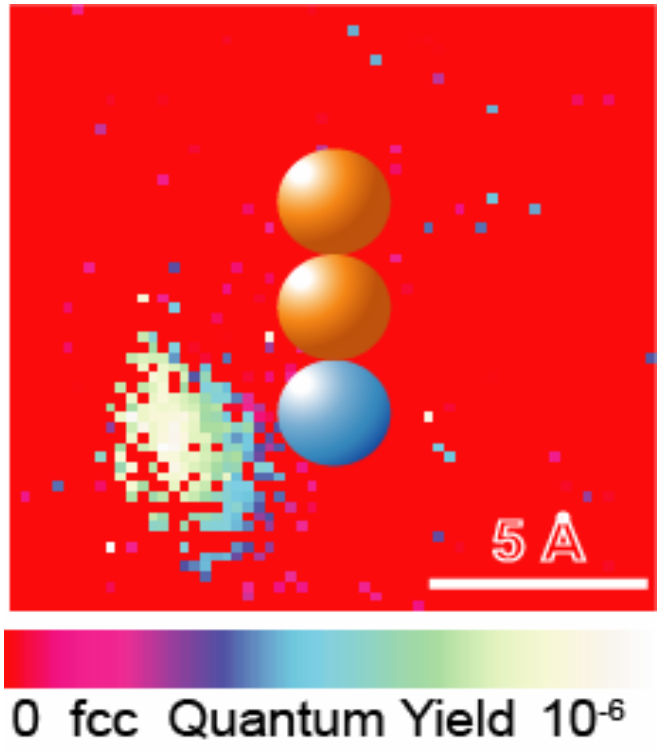
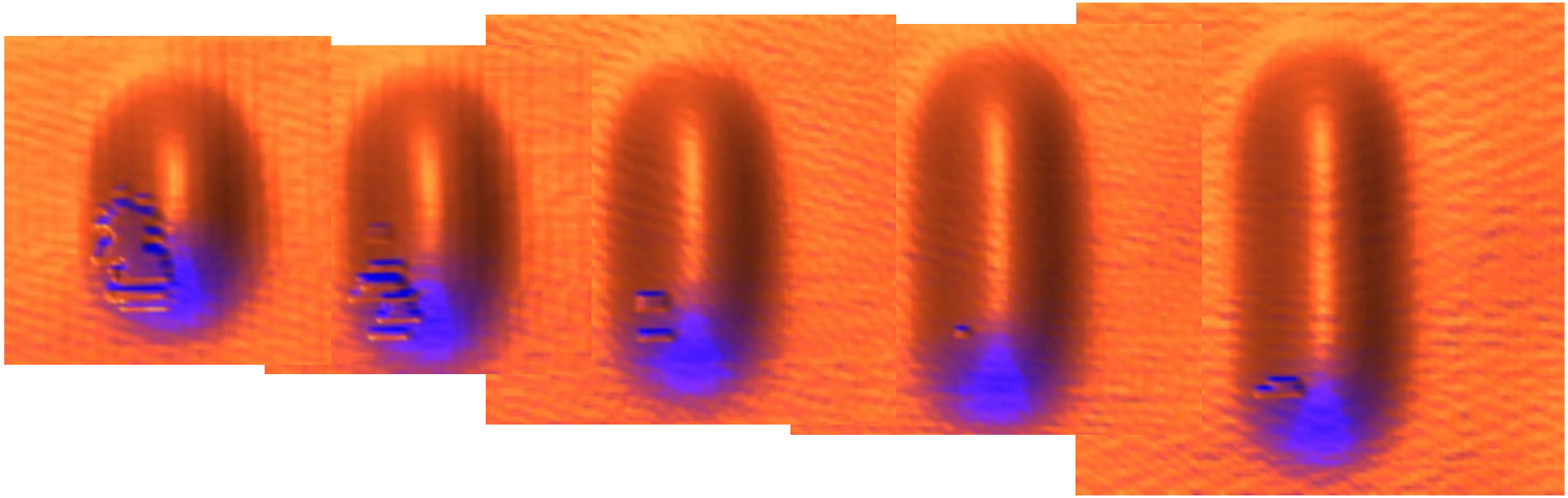


Side view of $CoCu_2$



Towards A Single Atom Switch

- To adjust the switching transition, adjust the atomic potential energy landscape by changing the molecular configuration



$CoCu_2$ $CoCu_3$ $CoCu_4$ $CoCu_5$ $CoCu_6$

J. A. Stroscio, F. Tavazza, J.A. Crain, R. J. Celotta, and A. M. Chaka, *Science* **313**(5789), 948-951 (2006)

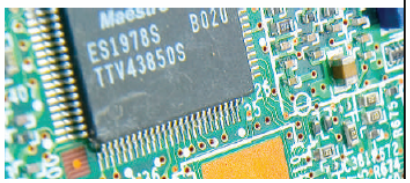
Graphene Electronics

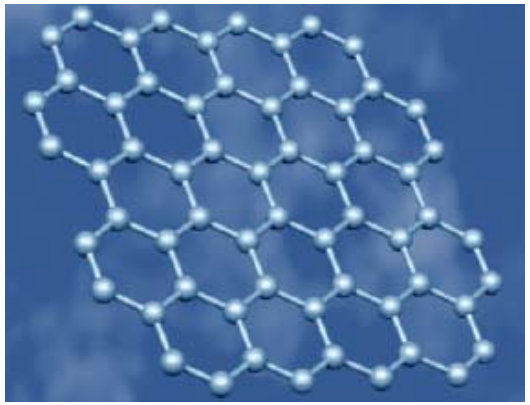
nature
Vol 442|20 July 2006

NEWS

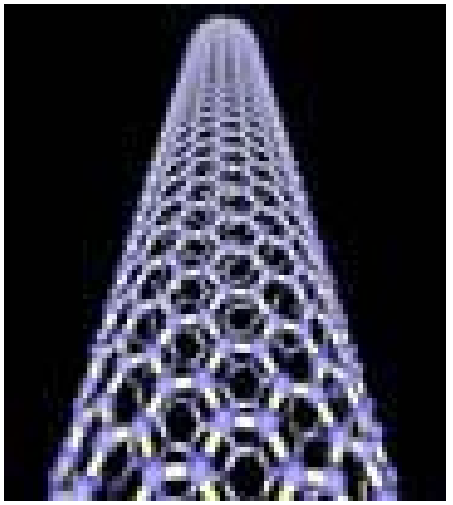
Moving towards a graphene world

Electronic Confinement and Coherence in Patterned Epitaxial Graphene





A Single Layer of Graphite,
i.e., Graphene



A Carbon Nanotube
(or a Graphene Cylinder)

New Projects Under Construction

- Developing measurement capabilities for:
  - Post-CMOS Electronics
    - Devices, architectures, interconnects
  - Nanomanufacturing and Nanofabrication
    - Top-down and bottom-up fabrication and assembly
  - Energy
    - Conversion, storage, and transport
- Complementary to and interactive with strong, existing laboratory programs
- Seeking scientific leaders to build programs
- Areas of concentration will, of necessity, change with needs

Developing Measurement Capabilities for Post-CMOS Electronics

- Characterization of Transport in Nanoscale Devices
  - Establishing a method and facility for nanoscale transport measurements
- 3D Measurement of Dopants and Defects
  - Application of atom probe and other methods to get a full 3-D picture of nanostructures
- Characterization of Nanophotonic Devices
  - Establishing the near range and far range interactions of nanostructures with light
- Spin Metrology
  - Detect spins with greater sensitivity and spatial resolution

Developing Measurement Capabilities for Nanomanufacturing and Nanofabrication

- Scanned Force Microscopy for Detection and Quality Control
  - Increase the speed, selectivity, and applicability of SFM
- Coupling Nanoscale Properties to Macroscopic Behavior
  - Computational framework to allow coupling nanodevices to the macro world
- Assembly of Nanoparticles
  - Measurement of the forces between nanoparticles in assembly
- Simultaneous Multi-function Nano-probe Measurement
  - Use of MEMs technology to establish multiprobe capability
- Tools for Manipulating Material on the Nanoscale
  - Integration of a variety of approaches to provide a nano-toolbox

Developing Measurement Capabilities for Energy Conversion, Storage, and Transport

- Nanoscale carrier dynamics
  - New probes of fast processes on the nanoscale to improve solar conversion devices
- Imaging catalysis at the atomic scale
  - New high temperature, high pressure imaging methods to allow the development of catalysts with greater efficiency in conversion and use of materials

What's Next?

- Open the Nanofab to outside users
- Begin an active and focused seminar program to better define research areas and identify talented scientists
- Continue recruitment of key project leaders and supporting staff
- Begin the fit-up and occupancy of new laboratory space
- Establish additional internal and external collaborations for the research program
- Continue to explore a variety of arrangements for sharing expensive equipment

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